DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 661—E

THE BOWDOIN DOME, MONTANA

A POSSIBLE RESERVOIR OF OIL OR GAS

BY

ARTHUR J. COLLIER

Contributions to economic geology, 1917, Part II
(Pages 193-209)

Published July 27, 1917

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CONTENTS.

ILLUSTRATIONS.

THE BOWDOIN DOME, MONTANA, A POSSIBLE RESERVOIR OF OIL OR GAS.

By Arthur J. Collier.

INTRODUCTION.

The Bowdoin dome is situated on Milk River, in northeastern Montana, on the main line of the Great Northern Railway between Malta on the west and Hinsdale on the east. (See index map, fig. 29.) It is about 42 miles south of the Canadian boundary, 150 miles

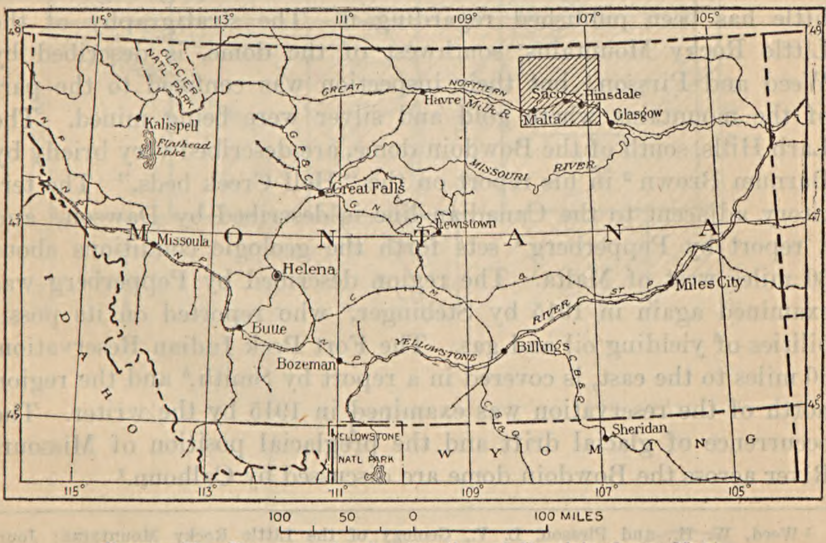

Figure 29.—Key map showing location of Bowdoin dome, Mont.

west of the Dakota-Montana State line, and 100 miles east of Havre. The dome is a broadly arched portion of the earth's crust from which the strata dip away on all sides, its structure being a type known to be favorable for the accumulation of oil or gas. in many fields. A well drilled here for water several years ago has been yielding a small flow of gas, sufficient probably for domestic use in one family, ever since, and it is thought that the region offers a chance of success to the driller of deeper wells. In 1915 a large gas well was drilled at Havre.

FIELD WORK.

During the summer of 1916 the writer, assisted by H. R. Bennett and Edwin T. Conant, made an extensive reconnaissance in northeastern Montana. The field work consisted of hastily riding over large areas, noting the outcrops of the formations, collecting fossils, and, whenever the presence of lignite beds or the geologic structure justified it, running traverse lines from section corners with the plane table and telescopic alidade. A section partly exposed on the east side of the Little Rocky Mountains was measured by this means, and several lines were run to determine the dips of the rocks. Many elevations were determined approximately by the aneroid barometer. A considerable part of the season's field work was applied to the examination and mapping of the Bowdoin dome.

AUTHORITIES CONSULTED.

The region has not been examined in detail by geologists, and little has been published regarding it. The stratigraphy of the Little Rocky Mountains, southwest of the dome, is described by Weed and Pirsson,[1] but their inspection was confined to the part of the mountains where gold and silver were being mined. The Larb Hills, south of the Bowdoin dome, are described very briefly by Barnum Brown [2] in his report on the "Hell Creek beds." The territory adjacent to the Canadian line is described by Dawson,[3] and a report by Pepperberg [4] sets forth the geologic conditions about 30 miles west of Malta. The region described by Pepperberg was examined again in 1915 by Stebinger,[5] who reported on its possibilities of yielding oil and gas. The Fort Peck Indian Reservation, 30 miles to the east, is covered in a report by Smith,[6] and the region north of the reservation was examined in 1915 by the writer. The occurrence of glacial drift and the preglacial position of Missouri River across the Bowdoin dome are discussed by Calhoun.[7]

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[1] Weed, W. H., and Pirsson, L. V., Geology of the Little Rocky Mountains: Jour. Geology, vol. 4, pp. 399–428, 1896.

[2] Brown, Barnum, The Hell Creek beds of the Upper Cretaceous of Montana: Am. Mus. Nat. Hist. Bull., vol. 23, pp. 823–845, 1907.

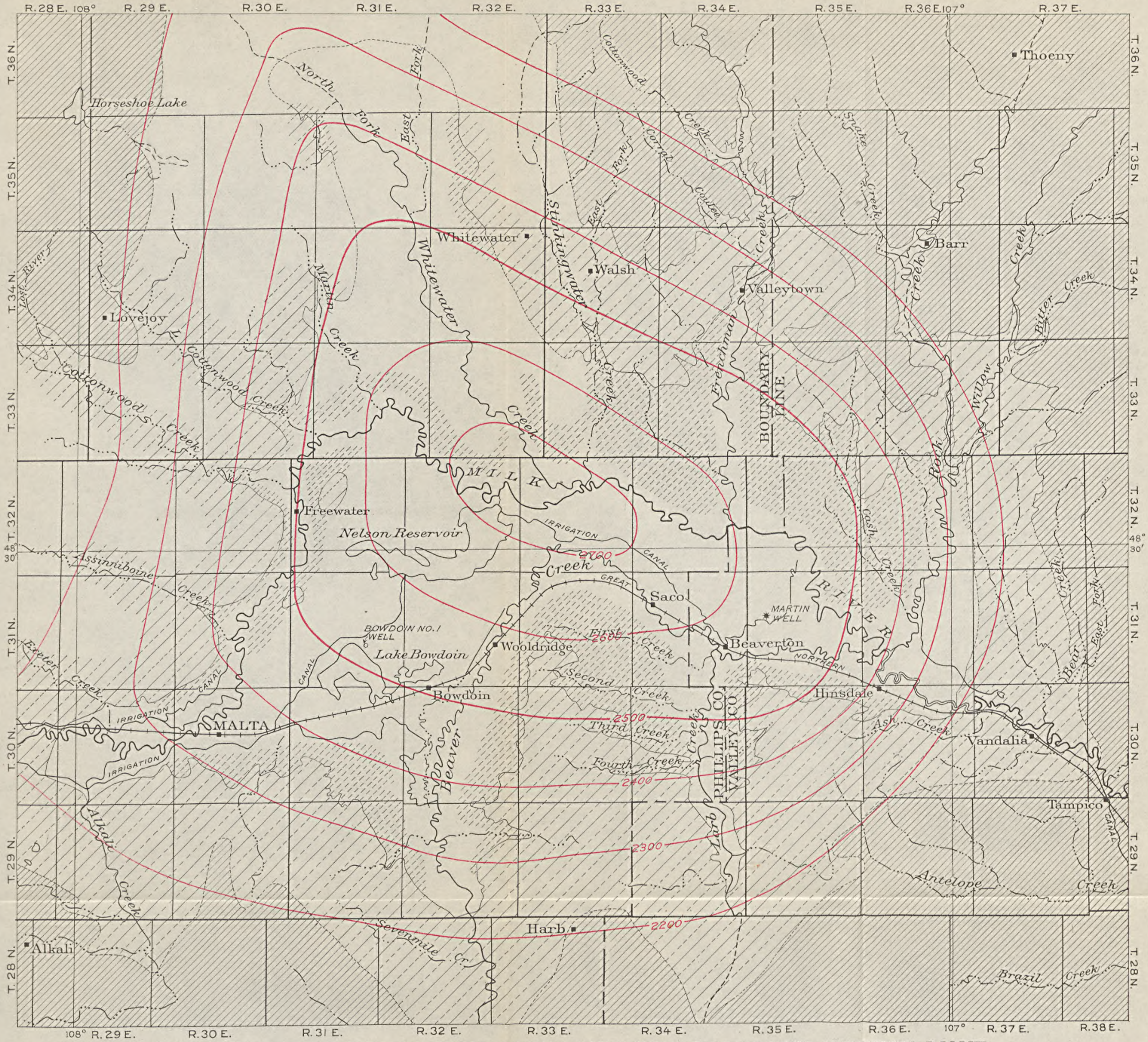
[3] Dawson, G. M., Geology of the forty-ninth parallel, British-North American Boundary Commission, Montreal, 1875.

[4] Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, pp. 82–107, 1910.

[5] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, pp. 49–61, 1916.

[6] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: U. S. Geol. Survey Bull. 381, pp. 40–59, 1910.

[7] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.



GEOLOGIC MAP OF THE BOWDOIN DOME, PHILLIPS AND VALLEY COUNTIES, MONT.

Scale $\frac{1}{375,000}$

10 5 0 10 MILES

1917

- Concealed by early Pleistocene beds, glacial drift, glacial moraines, and Recent alluvium
- Bearpaw shale
- Judith River formation
- Claggett shale
- 2300, 2200: Structure contours on the top of the Claggett shale (elevation above sea level)
- Gas well, small flow
- Oil well in process of drilling

BASE MAP.

The Bowdoin dome is included in Tps. 30 to 35 N., Rs. 30 to 36 E. Its southern part has been mapped topographically by the United States Geological Survey, and the approximate altitude of all points in this part can be found by consulting the Bowdoin, Saco, and Hinsdale sheets. The only reliable maps of the northern part are based on the township plats of the General Land Office. Many of the townships have been surveyed so recently that their plats are not yet available. Altitudes and topography along the international boundary are given on the sheet prepared by the International Boundary Commission, and the Geological Survey's topographic map of the Cherry Ridge quadrangle, 30 miles west of the Bowdoin dome, shows the altitude of the headwaters of some of the streams that flow into Milk River within the dome. The accompanying base map (Pl. XVI) is compiled from the Bowdoin, Saco, and Hinsdale sheets, the township plats, and the field notes made in 1916 by members of the Geological Survey party.

SURFACE FEATURES.

Much of the area lies in the broad valley of Milk River, which here coincides with the preglacial valley of the Missouri.[1] Its central part is covered by the alluvium of the old Missouri River and by glacial drift from a few feet to more than 100 feet thick. Milk River, Beaver Creek, Whitewater Creek, and Lake Bowdoin are all superposed on this glacial drift and thus have failed to expose the underlying rocks in their valleys. At Malta Milk River is about 2,257 feet above the sea, and at the Vandalia dam it is 2,120 feet—a fall of approximately 4 feet to the mile in a straight line. Beaver Creek enters this area from the south and falls even less than Milk River. Whitewater Creek, entering from the north, probably has a fall of about 10 feet to the mile from the international boundary.

Much of the area is included in the Milk River reclamation project and is owned by private individuals. A great deal of the valley land is on the flood plains and first benches of various streams and has a gumbo soil, but it can be made to yield good crops of blue joint and alfalfa by the use of water. Above the bottoms there are large areas of comparatively level land covered with glacial drift which are too high to be irrigated but which produce good crops of grain by dry-farming methods. North and south of the valley are highlands or benches that rise to elevations of 200 to 500 feet above the valley floor. Between these higher lands and the bottom of the

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[1] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50. pp. 45, 46, 1906.

valley are steep slopes on which the bedrock is exposed in many places and some badlands have been formed. The dome structure has been ascertained from these exposures bordering the valley, for within the valley itself bedrock can not be seen.

STRATIGRAPHY.

GENERAL SECTION.

The sedimentary rocks in northeastern Montana range in age from Cambrian to Recent, but only the Upper Cretaceous Claggett shale, Judith River formation, and Bearpaw shale, and some of the more recent surficial deposits are exposed in the immediate vicinity of the Bowdoin dome. The information regarding the rocks below the Claggett shale was obtained from observations in the Little Rocky Mountains, about 50 miles to the southwest; that regarding the Claggett and higher formations was obtained from a study of the outcrops around the dome itself. The time spent in the Little Rockies was too short to enable the geologists to determine very definitely the thickness and character of the formations that may be the source and receptacle of oil and gas. The relations of the strata above the Madison limestone are determined from only one set of measurements made on the east side of the mountains, and the determinations may be in error because of changes in dip or unrecognized faults. Owing to the poor exposure of bedrock in parts of this section it is possible that sandstones are present which were not recognized as such. The results of the measurement east of the Little Rocky Mountains and observations around the Bowdoin dome are shown in the following table:

General section of the rocks of the Bowdoin dome, Montana.

System.	Series.	Group.	Formation.	Thickness (feet).	Character.
Quaternary.	Recent.				Silts in the flood plains of streams.
	Pleistocene.				Scattered crystalline boulders; glacial moraines.
					Silt, sand, and gravel deposited along the old channels of the Missouri, Musselshell, and other streams before the end of the glacial epoch.
					Gravel interstratified with yellowish silt at an altitude of 300 feet above Milk River valley. May possibly be late Pliocene.
Cretaceous.	Upper Cretaceous.	Montana.	Bearpaw shale	800–1,000	Dark-gray shale; forms gumbo soil.
			Judith River formation.	400	Light-gray clay and irregular beds of gray and brown sandstone.
			Claggett shale.	750	Dark-gray shale; forms gumbo soil. About 500 feet exposed in Bowdoin dome.
			Eagle(?) sandstone.	100±	Light-gray sandstone; forms a low ridge; contains limestone concretions in its upper part.
		Colorado.		875	Bluish-gray to black shale; contains limestone concretions and marine fossils.
				60±	Light-gray sandstone, capped by a thin limestone containing numerous gastropods.
				485±	Bluish-gray to black shale.
			Mowry shale.	100±	Platy shale or sandstone, which is in places dark-colored but weathers white; contains numerous fish scales; yields traces of oil by distillation.
	Lower Cretaceous.		Kootenai(?) formation.	825±	Mainly shale but includes some poorly defined sandstone. In lower part red and purple shales were noted. A bed of fresh-water sandstone and carbonaceous shale with fragments of woody stems near the base.
Jurassic.	Upper Jurassic.		Ellis formation.	200±	Massive white and yellow sandstone.
				200±	Shale containing *Belemnites*.
Carboniferous.	Mississippian.		Madison limestone.		Massive limestone.

MADISON LIMESTONE.

The Madison limestone is the most striking formation surrounding the Little Rockies. It is the encircling girdle of the mountains in which the picturesque canyons of the streams are cut. Seen from the east these rocks appear like a great horizontal stratum, but on closer examination they are found to be turned up at high angles, and in the small outliers they are continuous over the tops of the hills. The rocks surrounding the Black Hills show a similar relation, and the Little Rocky Mountains have been described as being a miniature reproduction of the Black Hills. The Madison limestone is several hundred feet thick. It is fossiliferous throughout, and from the collections made G. H. Girty has identified at least 22 species and has determined the formation as identical with the Madison limestone of Yellowstone Park and other localities in Montana. It is of early Mississippian (lower Carboniferous) age, and in this area is a massive limestone.

ELLIS FORMATION.

Overlying the Madison limestone is a formation composed of shale and shaly and sandy limestones in its lower part and sandstone and shale in its upper part, and having a total thickness of about 500 feet. In its lower part it carries numerous specimens of *Belemnites* and *Gryphaea*. The detail of this part of the formation is as follows:

Section of lower part of the Ellis formation in the Bowdoin dome, Mont.

	Feet.
Shale with interbedded sandstone and limestone, containing gypsum and carrying abundant fossils	100±
Limestone, thin-bedded, shaly, and calcareous shale carrying fossils	200±

The fauna collected has been examined by T. W. Stanton, who reports that it is Jurassic and similar to that of the Ellis of Yellowstone Park and that of the Sundance formation of the Black Hills. As the Madison limestone is of Mississippian age, there is necessarily an unconformity between it and the Ellis, but the field work was not sufficiently detailed to make its recognition possible.

The upper part of the Ellis consists mainly of light-colored sandstone. The detail of the section as seen at one locality is as follows:

Section of the sandstone in the upper part of the Ellis formation in the Bowdoin dome, Mont.

	Feet.
Sandstone, massive, white, cross-bedded	50±
Shale, variegated	50±
Sandstone, yellowish, thin bedded	100±

KOOTENAI (?) FORMATION.

Variegated shale interbedded with yellow and brown sandstones, not well exposed in any part of the area examined, overlies the Ellis. The shale may be blue, green, red, or gray in places. The thickness given in the table (825 feet) was determined by one measurement and is only approximate. From 100 to 200 feet above the massive sandstone of the Ellis there is in one exposure a carbonaceous sandstone or sandy shale containing woody fragments and poorly preserved plant stems. In an exposure several miles away a conglomerate bed 5 feet thick was noted, but no measurement was made and its exact place in the column can not be stated. This formation is thought to be equivalent to the Kootenai (Lower Cretaceous) of other parts of Montana, though it may also include a representative of the Morrison formation.

MOWRY SHALE.

Above the Kootenai (?) formation a very well marked siliceous shale has been recognized at several localities and is the highest formation described by Weed and Pirsson in their paper on the geology of the Little Rockies. When freshly broken it is dark brown or black, but on weathering it becomes light colored and breaks into porcelain-like débris. It is characterized by the presence of fish scales, some of which can be found on nearly every piece examined, and in some places the trails of small marine animals were also found. Many reports of geologists working in Montana and Wyoming mention a shaly member containing fish scales and place it in the lower part of the Colorado group as the Mowry shale, with which this formation is correlated. Its outcrop around the Little Rocky Mountains is distinguished by a low ridge covered with small pines. The formation, however, may have a much more important relation to the Bowdoin dome than merely as a horizon maker—that is, it is thought to be a shale from which oil may be obtained by distillation. A small fragment of the shale was tested by distillation, and although only a slight indication of oil was obtained it seems almost certain that the formation would yield some oil if properly sampled and tested. The thickness of the formation is about 100 feet.

COLORADO GROUP ABOVE THE MOWRY SHALE.

The part of the Colorado group above the Mowry consists of three formations to which it is not thought advisable to apply any of the formation names used elsewhere in Montana without further field examination. Their total thickness is about 1,260 feet and their detail is as follows:

Above the Mowry shale there is about 325 feet of dark-blue shale, which differs slightly in color from the dark-gray gumbo shale higher in the section. The exposures seen are not continuous, and little can be said of the detail of this part of the section.

Above the blue shale is sandstone capped by a foot or more of impure limestone containing fossil gastropods and pelecypods, which have been identified by T. W. Stanton as belonging to the Benton shale. The stratigraphic position of this sandstone above the Mowry shale is almost identical with that of the Frontier formation of Wyoming and southern Montana. The thickness of the sandstone could only be estimated, and is given in the table as about 60 feet. The sandstone was seen at three localities, where it formed a low ridge. If this sandstone is continuous to the northeast as far as the Bowdoin dome it should form a good reservoir for oil or gas, and it should be reached by the drill before the attempt to find oil in this dome is abandoned.

Above the sandstone is a great thickness of bluish-gray to black shale, much of which is covered and concealed. The shale may include some sandstone or sandy phases that were not seen during the examination. The total thickness of the shale is about 875 feet. It is known to contain *Baculites*, a few specimens of which were collected from concretions.

EAGLE (?) SANDSTONE.

The Eagle (?) sandstone, which lies above the shale last described, is marked by a ridge about 30 feet above the surrounding country. The top of the ridge is covered with large limestone concretions, below which sandstone shows in some places. One imperfect fossil was found in this sandstone, but it is probably not determinable. The same sandstone was seen at a locality about 3 miles southeast of the point where the section was measured, and although it was not closely studied it was thought to be about 100 feet thick. This sandstone is about 750 feet below the base of the Judith River formation, and if it is the Eagle sandstone it proves that the overlying formation varies a great deal in thickness, for the Eagle sandstone is described by Stebinger[1] as being 350 to 500 feet below the base of the Judith River. In the area studied by Stebinger it consists of gray shale and sandstone in its upper part and white to buff massive sandstone in its lower part and is from 250 to 400 feet thick. This sandstone, if it extends as far to the northeast as the Bowdoin dome, is of importance in that it may contain oil or gas. The gas that has been found in the Bowdoin dome probably comes from the Eagle (?) sandstone, for it is estimated to be about 850

[1] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, p. 53, 1916.

feet below the base of the Judith River formation. In the Porcupine dome,[1] south of this region, between Missouri and Yellowstone rivers, the Eagle sandstone is lacking, being represented by shale.

CLAGGETT SHALE.

The Claggett shale, which overlies the Eagle (?) sandstone, is, by the single measurement made east of the Little Rocky Mountains, 750 feet thick. In the region investigated by Stebinger it is from 350 to 500 feet thick. It consists of dark-gray shale, containing marine fossils and carries a great deal of gypsum, concretions of aragonite, and calcite. Much of the aragonite shows cone-in-cone structure. The driller of a well in the Claggett shale reported passing through 22 inches of very hard rock, and it is probable that he encountered one of these hard concretions. About 400 feet of this shale is exposed in the center of the Bowdoin dome. Exposures along Milk River on the west side of the dome present the following relations of the Claggett to the overlying Judith River formation:

Contact of Judith River and Claggett formations west of the Bowdoin dome, Mont.

	Feet.
Typical Judith River formation:	
Shale resembling the Claggett	50±
Sandstone like the Judith River but containing marine fossils	20±
Typical Claggett shale containing many *Baculites*.	

North of the Bowdoin dome the section is about as follows:

Contact of Judith River and Claggett formations north of the Bowdoin dome, Mont.

	Feet.
Typical Judith River formation: Shale containing fossils similar to those in the marine sandstone	50±
Typical Claggett shale.	

On the south and east sides of the Bowdoin dome the marine beds that resemble the Judith River are lacking, or at least were not found. The upper part of the Claggett consists of brownish shale without *Baculites* and with little gypsum and aragonite.

JUDITH RIVER FORMATION.

Above the Claggett lies the Judith River formation, which is estimated, from several imperfect measurements, to be from 400 to 425 feet thick. The outcrop of the Judith River surrounds the Bowdoin dome and marks its area, standing out as a light-colored formation

[1] Bowen, C. F., Possibilities of oil in the Porcupine dome, Rosebud County, Mont.: U. S. Geol. Survey Bull. 621, p. 63, 1915.

in the hills on all sides. This formation consists of hard, brown sandstone; soft, friable, light-colored sandstone; and light-gray shale; but at no point in the formation were any beds found that could be traced far enough to mark definite horizons. In describing this formation Stanton and Hatcher[1] say:

> A detailed section taken at any point is of little value, since a similar section made at a distance of only a mile or two would give a quite different sequence of the alternating strata of sandstones and shales.

Some of the details of this formation may be seen from two sections made in its upper part on the east side of Rock Creek, as follows:

Section of Judith River formation on east canyon wall of Rock Creek, in sec. 20, T. 34 N., R. 36 E.

	Ft.	in.
Bearpaw shale.		
Sandstone, massive, grayish, with iron concretions scattered or in beds; weathers yellowish; some red bands; cross-bedded	32	0
Shale, brown, in places approaching lignite	2	0
Sandstone, soft, yellowish gray, and gray shale	23	0
Lignite		6
Shale, brown	1	0
Shale, gray	4	0
Shale, dark, carbonaceous		6
Shale, gray, and sandstone	5	0
Lignite		4
Shale, brown		8
Shale, gray	6	0
Shale, brown	3	0
Sandstone, soft, with iron concretions	1	0
Shale, sandy, brown	2	0
Sandstone, soft, gray	6	0
Shale, gray, clay	4	0
Shale, brown	3	0
Sandstone, soft, gray, and sandy shale	9	0
Sandstone; concretion bed	1	0
Shale, soft, sandy, gray	5	0
Sandstone; iron-concretion bed	1	0
Shale, blue and gray	4	0
Concretion	1	0
Shale, gray	4	0
Shale, brown	2	0
Sandstone, soft, gray and yellow	17	0
Sandstone, massive; weathers brown, arkosic (containing much feldspathic and ferromagnesian material); forms conspicuous ledges	7	0
Sandstone, soft, gray; some shale	20	0
Base not exposed.		
	165	0

[1] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, p. 34, 1905.

Section of Judith River formation in east canyon wall of Rock Creek, near line between sec. 32, T. 34 N., R. 36 E., and sec. 4, T. 33 N., R. 36 E.

	Ft.	in.
Glacial gravel.		
Sandstone, massive, gray; weathers yellow or reddish; some thin beds; cross-bedded	47	0
Shale, gray	6	0
Sandstone, soft, gray	2	0
Shale, gray	4	0
Shale, brown	3	0
Shale, gray	2	0
Shale, brown	1	0
Sandstone, soft, gray	5	0
Shale, brown, with 3 inches of lignite	2	0
Shale, gray	5	0
Shale, brown	6	0
Shale, blue	2	0
Sandstone, soft	9	0
Shale, brown	1	6
Sandstone, soft, gray	3	0
Shale, blue-gray	5	0
Concretions		6
Sandstone, soft, massive, gray	18	0
Shale, brown		8
Lignite		4
Shale, brown	5	0
Shale, blue-gray	12	0
Shale, brown	1	0
Shale, sandy	6	0
Sandstone concretion	1	0
Shale, gray	10	0
Sandstone, soft, gray	13	0
Shale, dark	3	0
Sandstone, soft, gray, and sandy shale	14	0
Shale, brown	2	0
Sandstone, massive, soft, gray or yellowish, weathering yellowish; certain beds weather out as massive reddish layers or as huge concretions; shows some cross-bedding	101±	
Base not exposed.		
	291±	

The base of this formation is not very definitely marked and can not everywhere be separated from the upper part of the Claggett shale. Its contact with the overlying Bearpaw shale is much more definite, although it has been seen in only a few places. The upper part of the formation consists of a massive sandstone in the two sections cited and in the neighborhood of the Little Rocky Mountains. At other points in the field this massive sandstone is not prominent, and in one or two places a small bed of lignite has been mined within a few feet of the top. Stanton and Hatcher report a layer of breccia consisting of shells of *Ostrea subtrigonalis* near the top of the Judith River formation as its most persistent horizon marker, but such beds were not seen at any point in the neighborhood of the Bowdoin dome.

BEARPAW SHALE.

The Bearpaw shale, from 800 to 1,000 feet thick, overlies the Judith River formation. It consists essentially of dark-gray shale which forms a gumbo soil and presents a monotonous and uninteresting landscape. This shale is exposed in many places along escarpments and canyons and forms badlands which lack the variety due to the presence of harder beds. The fossils are all of marine types; *Baculites*, *Inoceramus*, and oysters are very abundant, and occasionally the remains of a gigantic marine saurian are found. Much of the formation contains limy concretions, the lime being in the form of aragonite, showing cone-in-cone structures or appearing like the stumps of large trees. Calcite also is present in many of these concretions. The formation contains more or less gypsum, in the form of plates of selenite or in uncrystallized forms and replacing the calcite of oyster shells.

EARLY PLEISTOCENE OR LATE PLIOCENE GRAVEL.

A formation consisting of more or less cemented gravel interbedded with yellow silt overlies the Judith River and Claggett formations at an altitude of 300 feet above Milk River north of the mouth of Little Cottonwood Creek. Seen from a distance, it can easily be mistaken for the Judith River formation. A single fossil tooth was collected from this material and submitted to Dr. J. W. Gidley, of the National Museum, who identified it as a horse tooth resembling those of the living species.

PLEISTOCENE ALLUVIUM AND GLACIAL DRIFT.

The gravels and silts brought down by Missouri River when it occupied the present valley of Milk River, before the invading ice had forced it to flow through the narrow gorge south of the Larb Hills, appear here and there along Milk River, and such deposits are worked as gravel beds near Malta and Lake Bowdoin. They probably have a very wide distribution, but sediments of this kind are generally covered by glacial débris that was brought in by the ice when the Missouri was forced to abandon its old channel. Much of this glacial drift is in the form of boulders strewn over the surface, but in the northern part of the area, especially along Whitewater Creek, the material is very thick and shows the topography of a glacial moraine.

The deposits of alluvium and glacial drift are of considerable importance in the study of the Bowdoin dome, for they very effectively cover and conceal the underlying rocks and render it impossible to observe the center of the dome, about which little can be learned without the aid of the drill.

STRUCTURE.

The structure revealed by the Judith River formation in its outcrop around the valley of Milk River is that of a very broad, flat dome. The dips of the sandstone are so low as not to be detected by the unaided eye and are best recorded in feet to the mile. There is no place around the dome where a dip as high as 1° has been found.

On the northeast, east, and southeast sides of the dome the beds dip eastward for many miles; on the west side there is a westerly dip for about 35 miles to the neighborhood of Cherry Ridge. On the southwest the dips flatten, the top of the Judith River sandstone being about 100 feet above the river at Coberg, 28 miles from Malta, and outcrops of the same formation are reported to occur at intervals for many miles along the railroad. A dip to the south is indicated by the outcrops of the Lance and Fort Union formations near Missouri River. The only place where a dip large enough to be measured by a clinometer was found is in the Bearpaw shale in sec. 36, T. 36 N., R. 36 E., 30 miles northwest of the dome. Here an inclination of 5° northeast was recorded, but though search was made for similar dips in the rocks northwest and southeast of this locality they could not be found. It must be noted that dips in shale alone are difficult to determine, and that many shale beds show small superficial inclinations.

Along the outcrops of the Judith River formation there are large blocks of sandstone which have broken away and slid down the slopes. A notable instance of such slumping is to be seen near the mouth of Cottonwood Creek, where a large block lies on the east side of Milk River and has been tilted so that its bedding is not parallel with that of its original position. Features of this kind are very suggestive of faults, but it is thought that no real faults are present.

The amount of dip can be seen along Milk River between Hinsdale and Tampico. In this distance the fall of the river is so slight as to be negligible and the outcrop of the Judith River formation, about 400 feet thick, is about 10 miles wide. The dip to the east shown here is estimated to be approximately 60 or 61 feet to the mile, which is equivalent to 41′. Along Eagle Creek in T. 33 N., Rs. 36 and 37 E., a dip of 60 feet to the mile to the northeast was determined by survey with a plane table and telescopic alidade. Along Larb Creek the dip to the south is thought to be about 25 feet to the mile and along Beaver Creek there is evidence that the dip to the south is approximately 28 feet to the mile. West of Malta the dip to the southwest is about 27 or 28 feet to the mile, but along Cottonwood Creek, north of Malta, the dip to the west is much higher, probably from 40 to 60 feet to the mile. To the northwest, along Whitewater Creek, the dip is very much lower and probably does not exceed 15 or 20 feet to the mile.

On an ordinary topographic map the contours are drawn at definite intervals to connect points of equal altitude, and by means of them it is possible to show both the approximate altitude and the shape of the surface features. Structure contours[1] similarly show the relative altitude of different points and the shape of some definite stratigraphic unit. They are the best means yet devised for showing on a map the shape of such structural features as domes and synclines.

The structure of the Bowdoin dome is roughly represented in Plate XVI by contours on the base of the Judith River formation. The highest point reached by the uneroded base of the Judith River formation is at about 2,600 feet above sea level. Only the lower contours, from 2,200 to 2,400 feet, can be drawn with any certainty, and the highest contour, 2,700 feet, is wholly conjectural. In examining this map it must be borne in mind that the work done in this field was all of a reconnaissance nature. The southern part of the field had been topographically mapped by the United States Geological Survey, and the outcrops could be located definitely and their altitude determined, but such work has been done at only a few places. In the northern parts no topographic maps have been made. Altitudes along Rock, Frenchman, Whitewater, and Cottonwood creeks have been determined approximately by assuming these creeks to have a uniform fall from points along the international boundary and in the Cherry Ridge quadrangle to their mouths, whose altitude is known.

It must also be borne in mind that in the northern part of the field the outcrops are in many places concealed by thick deposits of glacial drift, which make the work of the geologist more difficult and may render it impossible to determine where the particular formations lie without the aid of a drill. The structure contours on the base of the Judith River formation were first drawn for the areas in which outcrops were available and then continued at the same dip over the areas in which the base of the formation had been eroded or was so concealed as not to be found.

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[1] Structure contours were first used on United States Geological Survey maps by M. R. Campbell in 1893 (Geology of the Big Stone Gap coal field: U. S. Geol. Survey Bull. 111).

In so broad a feature as the Bowdoin dome minor folds that would make parts of the area more favorable than others for the accumulation of oil or gas are to be expected, but the field work has not been sufficiently detailed to discover them if they exist.

One questionable feature of the Bowdoin dome is its flatness and the low dip (less than 1°) of the surrounding rocks. Many folds in the Ohio and Oklahoma oil fields[1] that have dips as low as those recorded in this field carry oil and gas, but such folds have not been found to be oil bearing in the fields on the flanks of the Rocky Mountains. The Glendive anticline, Montana, which carries gas, is marked by dips as high as 10° to 30° on the southwest side and 5° on the northeast.[2] The Salt Creek dome, Wyoming, which yields oil, has dips on the northeast slope of 8° to 10° and on the southwest slope of 15° to 20°.[3] The size of the Bowdoin dome is comparable to that of the Porcupine dome, near Forsyth, Mont., in which no wells have been sunk. The dips are higher in the Porcupine dome, being 1° to 8° on the north and east sides and 1° to 4° on the west side.[4] The structure of the Bowdoin dome differs markedly from that near the gas well at Havre, which is probably due to an upturned fault block of the earth's crust.[5]

APPLICATION OF THE ANTICLINAL THEORY.

The anticlinal theory relating to the accumulation of oil and gas, which in one form or another has been found to account for nearly all the large oil-producing fields in America, requires the presence of an impervious layer, such as shale, overlying beds of more open texture, such as sandstone, and below or within the open-textured beds disseminated oil and gas or beds from which these substances may be derived. The whole of this series of rock must be folded, producing anticlines or domes and synclines or troughs. In saturated rocks oil and gas collect in the anticlines—that is, the high parts—while water seeks the lower level in the synclines. The Bowdoin dome has a moderate anticlinal structure; an impervious layer is supplied by the Claggett shale; and the oil or gas may be concentrated in the Eagle sandstone at a depth of 400 to 800 feet, in the sandstone at a depth of about 1,600 feet, in the Mowry shale at about 2,100 feet, or in some one of the deeper sandstones. The

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[1] Condit, D. D., Structure of the Berea oil sand in the Woodsfield quadrangle, Ohio: U. S. Geol. Survey Bull. 621, pp. 233–249, 1916. Smith, C. D., The Glenn oil and gas pool, Okla.: U. S. Geol. Survey Bull. 541, pp. 34–48, 1914.

[2] Calvert, W. R., Lignite fields of eastern Montana: U. S. Geol. Survey Bull. 471, p. 201, 1912.

[3] Wegemann, C. H., The Salt Creek oil field, Wyo.: U. S. Geol. Survey Bull. 452, p. 54, 1911.

[4] Bowen, C. F., Possibilities of oil in the Porcupine dome, Rosebud County, Mont.: U. S. Geol. Survey Bull. 621, p. 66, 1915.

[5] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, pp. 69–72, 1916.

original source of the oil or gas may be the organic matter of the Mowry shale or some of the other shales and limestones below the Mowry.

INDICATIONS OF PETROLEUM.

The Martin well, drilled about four years ago in sec. 18, T. 31 N., R. 35 E., encountered gas at a depth reported to be about 640 feet. Though no test has been made, the supply is believed sufficient for domestic use in one family. The log of the well follows:

Log of Martin well in sec. 18, T. 31 N., R. 35 E., Mont.

[Furnished by Jack Rowe, driller.]

	Feet.
Gravel, sand, and surface soil	80
Shale with 22 inches of hard rock 140 feet from the top	555
Sandstone containing fish bones and gas	10
Shale	60

There is a 3-inch casing in the top part of the hole. Drilling was discontinued because the apparatus, an ordinary rig used in boring for water, was not suitable for reaching a greater depth. It is said that no attempt to learn the character of the gas by lighting was made until about a year ago, when it was found to be inflammable. Residents near by state that a bubbling noise could be heard about the well. A contrary report is that the gas had not been found at the time operations ceased, but that the well "drilled itself in"[1] subsequently. If this is true, it indicates that the gas is under considerable pressure, but in view of the conflicting reports no definite statement regarding it is warranted. When visited the well was filled with water within about 20 feet of the surface, and it could not be sounded because of trash dropped in from the top or mud forced in from below. Since the field season closed it is reported in a Saco newspaper that the gas from this well is being used in a heating stove. A well 80 feet deep near Vandalia is also reported to have obtained some gas, but as it is entirely in the Judith River formation this discovery is not important.

During the summer of 1916 there was a great deal of excitement in the search for oil and gas in the vicinity of Saco, and several companies were formed to prospect. Arrangements have been made to sink at least three wells within the Bowdoin dome. Two of these are to be north of Bowdoin Lake and a third somewhere north of Milk River, in the vicinity of Whitewater Creek. The Bowdoin Oil & Gas Co. has begun to drill one of these wells in the NE. ¼ SE. ¼ sec. 22, T. 31 N., R. 31 E.

[1] A technical expression, meaning that gas or oil under pressure forced an opening after the drill was removed.

CONCLUSIONS.

The Bowdoin dome has a structure which if found in Oklahoma or Ohio would be regarded as favorable for the accumulation of oil or gas. The surface is covered by the Claggett shale, below which, in at least four, sandstones that can be reached within 3,000 feet, there are chances of finding oil or gas. Of these four the Eagle sandstone yields gas at Havre, Mont., and probably it may yield gas in this field. The Frontier formation carries the most productive oil pools in Wyoming, and the heavy sandstone of the Ellis is capable of holding a great quantity of oil and gas. Samples of the Mowry shale resemble the oil shale (shale from which oil may be obtained by distillation) that has been prospected in Colorado and Utah, and it is thought that this formation may be an original source of petroleum. There are beds of carbonaceous matter in the Kootenai (?) rocks which, perhaps, correspond to the coal beds mined in the neighborhood of Great Falls. These beds may be a source of oil or gas. Below the Kootenai (?) there is a great thickness of shale, the Ellis, which may be another source.

In the writer's opinion the most favorable place to drill is in the highest part of the dome, which, as indicated by the structure contours, is near the northwest corner of T. 32 N., R. 33 E.

At the present time nothing can be predicted with certainty regarding the field. The structure, the positions of possible sources of petroleum, and the discovery of a small flow of gas certainly warrant a test. Whether or not commercial quantities of oil or gas exist must be left for the driller to discover, and will be ascertained in the near future if the arrangements that have been made are carried out.

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